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THE BURIED MORAINE OF THE SHUNGANUNGA.

By B. B. SMYTH, Topeka. Read before the Academy January 1, 1897.

Ice flows. Like all fluid and plastic substances it flows along lines of least resistance. When heaped high and unconfined at the base it spreads at the base and becomes lower at the top. When climate is such as to cause a continued accumulation of snow at a certain place, the continued pressure of the overlying snow has a tendency to solidify the underlying portions and convert into ice.

Such were the conditions during what is known as the glacial period over all the region south of Hudson bay. A long-continued period of cold induced congelation of the vapors from the Gulf of Mexico into snow north of certain latitudes, depending on the season. With reduced temperatures all over the northern hemisphere, as stated in Volume XIV of these Transactions, pages 223 and 224, snow would fall during winter north of 38° north latitude, and all the year round north of 50°. West of 100° west longitude there should be little accumulation of snow; because, unless the humidity was much greater than at present, the annual precipitation west of that meridian should be less than the evaporation, and snow should generally disappear, whether melted or not.

Hence it happens, conditions of moisture and prevailing winds being considered as well as temperature, that the greatest snowfall, and consequently the greatest depth of ice, should be south of Hudson bay and north and northeast of Lake Superior.

HEIGHT OF THE ICE.

If the snowfall during each year should be 2½ feet, which when partially melted and packed into ice would be about four inches, and this accumulation were continued through 12,000 years (see volume cited, page 223,) the height of the ice would be about 4,000 feet, to say nothing of the added height of unpacked snow on top of that. The evidences of advance of the ice to the south are that the ice, at its culmination, was fully that high from the west end of Lake Superior to the east end of Lake Ontario, and that the great lakes were frozen up entirely solid, or nearly so. But it is probable that the height of the ice north of Lake Superior was somewhat greater, as the snowfall must have been greatly in excess of three feet per annum for a very long time.

From the south end of Lake Michigan the ice was pushed southward; from the west shore of Lake Michigan the ice was pushed to westward of south; and from the west end of Lake Superior the ice was pushed to the southwest until it met the great ice field that was being pushed southward in the valley of the Red river; thence it was deflected to the south.

Whatever the height of the ice was over Manitoba, or over Ontario north of Lake Superior, it was sufficient to push its foot clear down to Kansas, as shown by the drift and other glacial material in the northeast corner of the state, and by the line of boulders across the corner of the state on the outer margin of this drift area.

But suppose the ice in Ontario were not of sufficient height to push its foot into Kansas. It had a valuable ally in the great Missouri. Between Ontario and Kansas the Missouri flows over a vast tract of elevated plain situated for the most part, with its tributaries, west of the one hundredth meridian, and therefore in the arid region west of the glaciated area. The Missouri was shut out from reaching Hudson bay, and compelled to flow southward along the western margin of the ice field, making a new channel for itself. When the waters of the Missouri flowed down to the base of permanent ice, they became frozen and filled the valley — such as it was, ice on one side and land on the other — with ice, until the waters could flow to the eastward into the Des Moines river, in Iowa, and into the Grand river, in north Missouri, and westward until an elevation was reached commensurate with, though not equal to, t e height of the ice.

The sands, muds and ground-up limestones that were carried down by the waters of the Missouri overspread the ice and found lodgment, on its subsequent melting, wherever it was carried to. Thus it is that we find what is called "loess," or Missouri river deposit, nearly everywhere in Marshall, Pottawatomie and northern Shawnee counties; in some places 60 to 75 miles from the present Missouri river.

This ice must have made the passage easier for the stones that were carried from the north; for we find boulders from Ontario arranged in a line along the outer margin of this loess-covered region, from Hollenberg and Hanover, Washington county, by way of Olsburg, St. George, and Wamego, Pottawatomie county, McFarland and Maple Hill, Wabaunsee county, Mission Center, Berryton, and Richland, Shawnee county, Belvoir, Clinton, and Sibley, Douglas county, to near Olathe, Johnson county.

DIRECTION OF ICE FLOW.

The ice pushed southward across the Kaw river all the way from Wamego to Kansas City, and reached an extreme distance south of the Kaw of nine miles south of Topeka and 13 miles south of Kansas City. Thus the Kaw was blocked for a short time, but not to cause it to overflow across the divide into the Osage, except possibly for a very short time.

Wherever in Kansas any evidences are to be seen regarding the direction of ice flow, the ice seemed to radiate by curved lines, from nearly straight south in the Missouri valley to west of south in the Delaware valley, 30 miles to the west, and to south of west in the Blue valley, 75 miles to the west.

At Kansas City a few scratches seen on the limestone rocks and reported some time ago indicate a direction of ice flow a few degrees east of south. Scratches, however, are very scarce; they have all, if any ever existed, been worn away long ago.

At Lawrence, all indications seem to be that the ice flowed nearly straight south. Mount Oread, upon which the university stands, is a ridge standing directly north and south. It has had its sides sharply planed by the ice, which must have flowed nearly parallel. If there were any difference of pressure upon its sides, its east wall would seem to have been smoothed the best; though pressure there was not strong enough to carry any of the stones over the crest of the ridge. Indeed, there is no evidence on the south end of the ridge, where the university stands, that the ice passed over the hill at that point; though farther north, where the ridge is lower, there are boulder clay and small quartzite pebbles at one or more points, showing that the ice passed there. The high northern end, overlooking the Kaw, has not been examined.

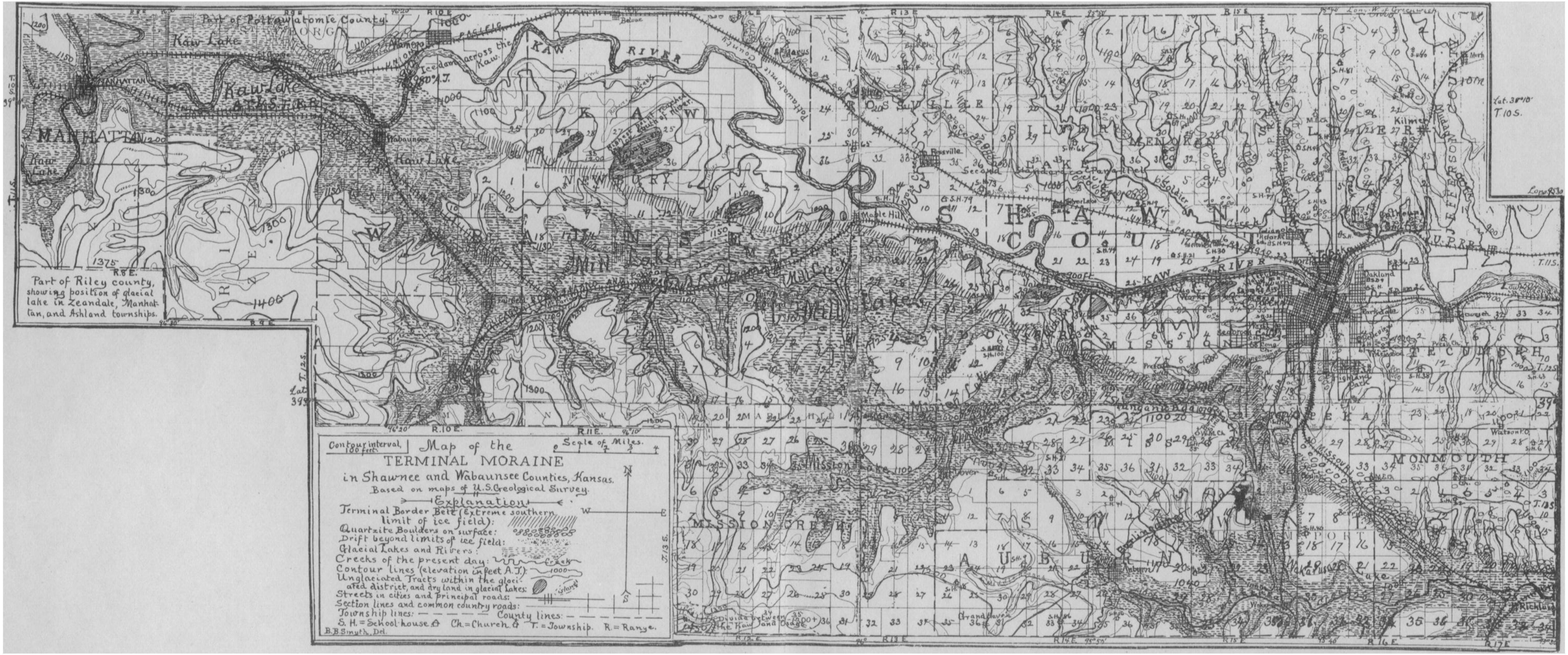
At Topeka the direction of ice flow seems to have been south 17 degrees west. There are no scratches on the rocks. The only evidences are the general trend of the three parallel ridges upon which the city is built and the general trend of the moraine in front, which is exactly perpendicular to those ridges.

Further west the principal evidence of ice flow is the general trend of the moraine, which is generally perpendicular to it.

COURSE OF THE MORAINE.

The line of the moraine, as it crosses Shawnee county, is thus: Commencing at the east line of the county about three miles north of the southeast corner of

PLATE I.


Map of the
TERMINAL MORAINE
in Shawnee and Wabaunsee Counties, Kansas.
Based on maps of U.S. Geological Survey.
Contour interval, 100 feet.
Scale of Miles.
0
1
2
3
4
Explanation.
Terminal Border Belt (Extreme southern limit of ice field):
Quartzite Boulders on surface:
Drift beyond limits of ice field:
Glacial Lakes and Rivers:
Creeks of the present day:
Creek
Contour lines (elevation in feet A.T.):
1000
Unglaciated Tracts within the glaciated district, and dry land in glacial lakes:
island
Streets in cities and principal roads:
Section lines and common country roads:
Township lines:
County lines:
S. H. = School house
Ch. = Church
T. = Township.
R. = Range.
N
S
E
W
B.B.Smyth, Del.
Part of Riley county, showing position of glacial lake in Zeandale, Manhattan, and Ashland townships.
Part of Pottawatomie County.
Pottawatomie County
Jefferson County
MANHATTAN
Kaw Lake
Kaw River
Wabaunsee
Mill Lake
Mill Creek
Mill Lakes
Mission Lake
Mission Creek
Rossville
Silver Lake
Maple Hill
Wakarusa Lake
Auburn
Monmouth
Tecumseh
Dover
Soldier Creek
Ice dam across the Kaw.
Lat. 39°
Lat. 38°40'
Long. W. of Greenwich
96°20'
96°10'
R.10 E.
R.11 E.
R.12 E.
R.13 E.
R.14 E.
R.15 E.
R.16 E.
R.17 E.
T.10 S.
T.11 S.
T.12 S.
T.13 S.
1000
1100
1200
1300
1375
1400

TERMINAL MORAINE AND GLACIAL LAKES IN SHAWNEE AND WABAUNSEE COUNTIES, KANSAS.

the county, it traverses the county westward and crosses the west line of the county about 10 miles north of the southwest corner. Its length in the county is about 30 miles, though the county is but 24 miles across.

For 10 or 12 years, since teaching at Richland, I have been interested in tracing out this line in the eastern part of the county, and have walked repeatedly over every foot of it from the east county line to Burnett's mound. The boulders are found continuously on the south edge of the bluffs north of the Wakarusa from the east line of the county to the mouth of Lynn creek. The boulder belt follows up Lynn creek to Tevis and Berryton, and continues in the same general course past Pauline and school district No. 11 to the southwest quarter of section 23 (township 12 south, range 15 east), half a mile from the ridge running south from Burnett's mound. Here it turns sharply to the north and runs along the crest of a ridge on the west side of sections 23 and 14, across the M. I. Lee place and to the Hoffman farm, on section 11, just south of the Shunganunga, two miles north of the turning point. Here it disappears.

A recent attempt, after much previous searching, to find the lost moraine, in company with Dr. Wm. Smith, sr., resulted in finding it in an unexpected place, namely: covered up in the bottom of the Shunganunga creek, and extending for two miles up the valley of the creek. It reappears on the Hammond place, at the southwest corner of section 16, south of the creek and in a line with that part of moraine east of the mound. From this point it continues across the county in a line north of west, agreeing with that portion in the eastern part of the county.

The Buried Moraine.

The first evidence of it in the creek bottom is by the creamery south of Seabrook, and just northwest of the Hoffman place. Here there are a number of large boulders, the largest nearly spherical, and about five feet in diameter. They are well water-worn, as are all boulders lying in the bottom of the creek.

I had no difficulty in tracing the moraine up the valley of the creek, although there was no evidence of it at the surface; for, walking southwestwardly in a straight line in the direction I believed the moraine ought to lie, every time I came to a bend in the creek I saw boulders in abundance in the creek bottom, even to a depth of three feet at the middle of the moraine. At such places the boulders were visible in the banks up to a height of 10 feet or more. Wherever the creek crosses the moraine at right angles the breadth across it, measuring along the bed of the creek, is from 25 to 40 paces. Going down stream, and approaching the moraine, the bottom of the creek slopes upward, until the middle of the moraine is reached, then it slopes rapidly downward. The difference in level of the mid-morainic and non-morainic portions of the creek bottom is about three feet; that is, the non-morainic portions of the creek bottom would need to have three feet or more of water before it would commence flowing over the boulders farther down.

The banks of the creek are generally about 25 feet high. The lower 10 or 15 feet is composed of drift material and boulders; the upper portion is native earth, washed in from the surrounding hills, effectually obscuring the boulders except where exposed by subsequent wash.

At one of the southerly bends or loops, say the third from the creamery, the creek reaches the moraine from the northwest, turns and runs along the top of the moraine for about eight rods, then turns and runs off to the north again. This stretch is paved with boulders. Near the middle of the bend several blocks of limestone lie on top of the boulders in such a way as to indicate that they had fallen from some overhanging cliff on the south side of the creek. An inspection of these blocks, which contain a few fusulina and a very few other fossils, showed that they had belonged in the limestone stratum just above the coal; though that was nowhere in sight. The south bank of the creek at this point appears entirely of drift material. Boulders occur in the bank to a height of 15 feet. One boulder about 16 inches in diameter was held bound between the roots of an elm tree nearly three feet in diameter, near the top of the bank. The height of that boulder above the bottom of the creek is a trifle over 15 feet. The tree is firmly rooted in the bank, and has not yet begun to topple over, although several of its large roots are exposed.

At another similar bend up the stream — call it the fifth — the creek cuts entirely through the moraine, and runs parallel with the moraine and partly on top of it for a distance of about 10 rods. Along this course the creek has cut forward into the original undisturbed strata south of the creek for an apparent depth into the bank of four to eight feet or more. The coal stratum, where not covered with talus, is here plain to be seen about 15 feet above the creek bottom. It is overlaid with a stratum of shale about 18 inches thick, and this is covered with a solid stratum of limestone 2½ feet thick. This accounts for the blocks of limestone in the other bend below. The creek, in coming from the northwest, strikes the original bank at an acute angle, so that the drift portion of the bank thins out until it disappears, and the bank of native strata succeeds eastwardly. The bank here is vertical, slightly overhanging at a height of about 18 feet. The line of junction between the native and the drift portions of the bank is vertical, and can be distinctly seen from a height of 8 feet up to 20 feet. Here the drift boulders are jammed into the vertical face of the original bank, some of them so firmly that they still cling to the face of the native bank, though the supports have been removed by the creek. The front edge of the limestone stratum at this point is slightly lifted and the boulders and drift material jammed and wedged firmly in under it for about one or two feet. This illustrates the tremendous pressure that was exerted upon the drift material as it was being pushed from the north. The lower eight feet of the line of junction was not seen, being obscured by talus, and the time taken for examination did not admit of any digging. A few rods further up the creek, where the drift bank is exposed to the base, the drift material reaches down to the bed of the creek, and how much deeper is not known.

At the sixth bend, the creek, after crossing the moraine to the south, does not run along the moraine, but has cut a new channel to a distance of about 15 rods into the original stratified earth, then turns and recrosses the moraine to the north. This portion of the creek was not examined. The length of the paved portion of the creek here is 45 paces. It is slightly diagonal across the moraine.

At the upper end of the next bend the coal is just above the paved bed of the creek, and here it is worked. Here a straight cut-off comes from the bend further up. It passes on the north side of the moraine, and is parallel with it. This cut is about 150 feet long and 25 feet wide. It has vertical banks 20 feet high, apparently fresh, and its floor is naked limestone, about three feet higher than the bed of the creek. On the south side of the cut, boulders appear in the bank to a height of 10 feet; on the north side drift clay, small boulders, and pebbles, partly stratified, from the clean rock floor up to a height of eight feet, then mixed with prairie earth, gradually changing to clear prairie earth above.

There are no glacial scratches on this floor. Possibly, if there ever were any, the overrunning water and pebbles have worn them away; though the water does not run in the cut unless it is at least three feet deep in the creek above; otherwise, it runs around in the old channel. No effort was made to discover any scratches on that portion of the limestone floor that is covered with drift;

though it is not all probable that any existed there. The current on the lime stone floor must have been too strong. Then, too, the glacial deposit must have been partly dumped there and partly washed down the current of the stream, in addition to being pushed from the north.

The buried moraine was followed no further in the bed of the creek. The spot last mentioned is on section 16, northwest of the mound. Half a mile further up, about Burnett's old cabin, there are very many boulders, some of them of good size, both in the bed of the creek and on the north bank.

UPPER SHUNGANUNGA.

Still another half mile up, the moraine emerges from the creek on the Hammond place, near the south line of section 16. Here it forms an east-and-west ridge south of the creek about 15 feet in height above the prairie, and apparently 10 feet or more in depth of drift material. The total distance to this point from where the moraine disappears in the bottom of the creek is a little over two miles, and its course is south 65° west. On the Major Sims place, on section 17, the moraine is on both sides of the creek, thus being double at this point. On the north side his house is built on the morainic ridge. The well, 18 feet deep, is entirely in drift. Water is abundant and unfailing. From the Hammond place the moraine continues its regular course of north 67° west across the county.

Two miles west of Mission Center the moraine is entirely on the north side of the creek. The broad valley of the creek is gone. It here consists of a gorge about 50 feet deep and not 20 rods wide. A little further west the depth of the gorge increases and the water flows west toward Blacksmith creek. The bank north of the gorge is covered with drift and boulders; the south bank is capped with fusulina limestone three feet thick.

ADVANCE MORAINE.

Nearly half a mile south of this, resting high and dry on the sloping prairie, there is an outlying border belt, a sort of advance moraine, as it were, of fusulina limestone boulders. They are composed almost solidly of fusulina shells and no other fossils; so their horizon is unmistakable. Here, they are stretched east and west across the prairie fully 20 feet above their locus, and more than a quarter of a mile south of the bank from which they were lifted. If they were also carried down stream, as well as pushed across to the south, then they were lifted more than 20 feet; because the strata dip toward the west.

This would seem to indicate that the local ice of the valley had been pushed up out of it, carrying the top of the ledge of rock with it. Subsequent thawings, refreezings, and pushings, in advance of the glacier, and at its foot, succeeded in working these rocks to their present position. It would also indicate that the influence of the glacier was felt long before its foot reached the Shunganunga.

REFLECTIONS.

From these observations I would draw the following conclusions:

1. This Shunganunga creek existed during glacial times very much the same as it is now.
2. When the ice-field reached the creek in its southward progress, it crossed the lower portion of the stream as far up as section 11, half a mile northeast of the mound.
3. From that point, near the creamery, up to and beyond Burnett's cabin, a distance of two miles, the ice never crossed the Shunganunga, except for a very short time.
4. The ice never touched Burnett's mound, though it stood around it on three sides to a height equal to or greater than the top of the mound.

5. A strong torrent washed the base of the ice on the west, north, and east sides of the mound, laying bare the bed-rock, and even cutting through it north of the mound.

6. The water escaped east of the mound by overflowing at Pauline into the Wakarusa.

7. The ice on the north side of the mound dumped its load into the bottom of the denuded Shunganunga valley.

8. This deposit was not merely dropped, but was pressed heavily against the foot-wall on the south side of the valley.

9. This deposit was afterward covered up by wash from the surrounding hills, and so rendered invisible except where subsequently exposed by the creek.

Glacial Lakes.

An ancient shore-line is distinctly to be seen surrounding the mound at an elevation of about 50 feet below its summit. About 30 feet below this a second shore line is seen. This lower one is nearly 200 feet in breadth on the north side of the mound. This follows along the hillside to the west as far as the eye can see. It passes around the mound to the east side, and follows the side of the ridge to the south as far as one can see from the mound.

In the Wakarusa valley a glacial lake was formed, reaching from three miles below Richland, where the ice-field crossed the Wakarusa, back to Auburn, a distance of 20 miles, and having an average breadth of three to four miles.

Allowing levels to be the same then as now, the depth of the Wakarusa lake, near Belvoir, its deepest place, was 250 feet; at Richland, 200 feet; at Wakarusa station, 150 feet; and at Auburn, about 50 feet.

The depth of the Shunganunga river, at its deepest place, north of the mound, was 125 feet, and in the shallowest part of the gorge, connecting its head with Blacksmith creek, was 75 feet.

A glacial lake formed on Mission creek, extending from the Moon road-crossing back southwestward into Wabaunsee county 15 miles. Its breadth was about two miles. It overflowed across Blacksmith creek into the Shunganunga river.

A glacial lake formed on Mill creek, reaching from Maple Hill westward away beyond Alma, and southward about seven miles. Its deepest place was at Maple Hill, exceeding 200 feet. It overflowed southward into Mission lake. The top of Buffalo mound, like the top of Burnett's mound, stuck up out of water.

The greatest lake of all was formed on the Kaw, from Wabaunsee up past Manhattan, westward on the Smoky hill to Salina, and northward on the Blue nearly to Blue Rapids. All the waters of this Kansas lake overflowed through the valley between Wabaunsee and McFarland into Mission lake and later through the Shunganunga river around Burnett's mound. The depth of this Kansas lake at Manhattan was a little over 150 feet.

On retreat of the glacier the Wakarusa ran out first, followed by the Shunganunga; this in turn was followed by the Mission lake; next the Mill creek lake was free to run into the Kaw. Finally the glacier retreated from the Kansas river between Wamego and St. Mary's, and the Kaw was open over its whole course. Had the glacier lingered longer until 75 feet more of earth were removed in the valley between McFarland and Wabaunsee, the course of the Kaw would have been changed into the valley at present occupied by Mill creek.

Small icebergs floating in these waters account for an occasional boulder and a little drift material south of the moraine.

NEW VISIT.

In 1895 a new visit was made to the buried moraine in company with Prof. F. W. Cragin, of Colorado Springs, and Dr. Wm. Smith. One object of the visit was a confirmation of the assertion that the boulders were pressed into the south wall of the valley, as described in the "fifth bend." By some mischance that particular bend was overlooked, showing that a miscount was made either on one or both trips; and while the oversight was suspected, it was not positively known until the "cut-off" was reached; and it was then decided not to retrace. The point was neither reaffirmed nor refuted.

Another point we desired to know was whether the southwest sides of the boulders were more highly polished than the other sides, as observed in the moraine near Blacksmith creek (a point mentioned in an article read before the Academy of Science in December, 1894.) *

LEE MORAINE.

The particular portion of the moraine examined was the two-mile north-and-south strip east of Burnett's mound. The statement was not confirmed here. The most highly polished side was not oriented in any direction. Directions were various and about equal. This may be because the moraine trends north-and-south, and the boulders are thus protected from the prevailing winds.

Observations were limited to the half mile on the Rowles place, along the west line of section 23 and just south of the old M. I. Lee place. The ridge here appears to be composed entirely of drift, and there are many large boulders. Half a dozen metamorphic sandstone boulders were found that were incrusted more or less up to one-eighth of an inch in thickness with a brown ferruginous sand. On removing this incrustation with a sharp implement and some force, the face of the stone was seen to be polished the same, or about as much, as where the stone is exposed. If stones had been imbedded in a bank of iron sand during one or more interglacial epochs previous to the Kansan epoch, then they were polished before they were deposited in the bank of iron sand, and not by dust attrition since they arrived here. Is this reading the lesson correctly? Then again, it is as reasonable to expect, if they had been deposited together before, they would be taken up at the same time in the advance of the ice during the Kansan epoch and deposited together here, as that they would be scattered many miles apart along our moraine. However, similarly incrusted stones are to be found elsewhere.

This two-mile strip of moraine is nearly level along its crest and does not vary in elevation perhaps more than 25 or 30 feet at different points. The highest point is near the north end, about half a mile south of the Shunganunga which comes close to the north end. The moraine is from 200 to 300 paces across, and from 30 to 50 feet higher along the middle or crest than along the sides, where it changes to prairie earth containing some drift but no boulders.

On the Rowles place, on section 23, half a mile south of M. I. Lee's house, the ridge is bisected by a preglacial gap, through which runs a branch of Colby creek, flowing northward into the Shunganunga. Its depth is about 85 to 90 feet; its breadth 12 to 15 rods at the bottom. It cuts the ridge squarely across. The little stream, after passing through the gap, turns to the north. The floor of the gap is glacial drift. A new well for stock is dug close to the north bluff. The well is about six feet deep. A limestone ledge, two feet thick is at the top of the well, at the base of the bluff. The material in the side of the well under the limestone ledge is drift. All the earth thrown from the well is drift clay and

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*See Trans. Kan. Acad. Sci., XIV, p. 225.

small boulders. The bottom and banks of the little creek are of prairie earth, with a few small boulders. It is probably underlaid by drift. About 10 rods east of the well, in the north bank of the gap, there is a small vertical washout at the base of the bluff, up to a height of 40 feet. The depth of the washout into the bank is about eight feet. Its sides hold grass and shrubs. At the bottom, which is fresh, the native strata in the hill are exposed. The deposit at its foot forms a truncated semicone about five feet high and 60 to 80 feet across. It is mostly glacial material. The entire end of the hill, as well as the sides of the ridge, is covered with glacial drift.

About 50 feet above the base of the bluff, and about 40 feet below its summit, the edge of a stratum of limestone crops out at the south end of the ridge. Very little of it is to be seen through the enveloping drift. Some pieces of the limestone are lifted slightly from their position, upturned, and pushed around toward the west. They are held in that position by the packing of drift material about them.

In passing down the sides of the hill in any direction it is difficult to determine, without digging, where the solid covering of drift ends and the superficial covering, or talus, begins; as drift covers the entire upper surface of the hill down to 50 feet or more. But, using our best judgment, Professor Cragin and I estimated a thickness of 30 to 35 feet of drift on top of the ridge. If it be supposed to be all drift above the limestone, it would be about 40 feet. Elevations were made with an eye-level and an aneroid barometer.

This moraine contains boulders of local rock in addition to the quartzites and metamorphic sandstones. Especially noticeable were some blocks of purple-brown ferruginous sandstone filled with large irregular nodules of snuff-colored or brownish-yellow ochery clay. This is before spoken of as argillaceous ironstone. I have seen this in the Dakota sandstone in central Kansas, but do not know where it outcrops north of here; probably not within the state.

Broken stones were frequently noticed in the moraine. Some of the sandstones and conglomerates were separated along planes of stratification, through the ordinary process of weathering; but some sandstones and quartzites were split across through the solidest part, as though done through concussion or shock. One quartzite boulder, 10 feet in diameter, half a mile east of Burnett's mound, is broken into three pieces. The pieces lie close together with the fractured faces facing each other. The interior faces are rough and covered with lichens. Other large fractured boulders are known elsewhere.

How Boulders Break.

How to account for the breaking of these stones is a problem. I hesitatingly offer this solution:

A stone fell from the ice and struck another. If the perpendicular height of the ice front were, as before stated,* equal to or greater than the height of Burnett's mound, it would be, say 100 to 200 feet. That fall would of itself be insufficient to break a stone, when 75 feet of that distance was through water and floating ice. Observations made on glaciers by other observers have shown that, though dirt and small pebbles sink into the ice during sunshine, the rays of the sun do not penetrate large stones, but they act as a protection to the ice underneath. Stones carried in the middle of a large ice-field will, in the course of time, reach the surface by the melting of the superjacent ice as the ice is pushed to the south. At the surface the surrounding ice becomes melted until the boulder stands on top of a taller-growing pedestal of ice. *

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* See Trans. Kan. Acad. Sci., XIV, p. 222.

An ice-field covering most of Iowa, northern Missouri, northeastern Kansas, and eastern Nebraska would be thinnest at its edges, whatever that thickness might be. It would be thickest along its middle line, and increase in height to the north until the snow-field was reached. The rate of ascent on a level plain has been estimated by various observers at 25 to 75 feet to the mile. The ascent should be most rapid from the south, by reason of the more rapid melting and the greater pitch of the earth's surface in that direction.

A field of ice that is spread over a plain should have the smoothest surface of any form of glacier. Rain or melted ice would simply run off, seeking the shortest cut to the ground. No need to account for interglacial streams or vast crevasses. While most likely the margin was deeply cut everywhere by water running down, the upper portions of the field must have been comparatively smooth and solid. It should resemble the remarkable Fan glacier of Redcliff, pictured and described by Professor Chamberlin in Journal of Geology, Vol. III, No. 4, p. 470, only on a vastly grander scale and sloping downward much less rapidly. But the slope should be continuous, and constantly increasing as the edge of the field was approached.

When our field reached its greatest southern extent and began to retreat, the weather of July must have been hotter and moister than at present because of contiguity of the earth to the sun and of the Gulf of Mexico to the ice. A hot south wind blowing for three days as at present should remain above the freezing point for several hundred miles over the field of ice. Is it too much to say the surface of the ice would melt for 500 miles north of Kansas City? The ice would be melted by rainfall as well as by sunshine. A southwest wind would bring as much heat and much less moisture. In either case the surface would melt except where protected by the large boulders, whose pedestals were still growing taller.

If we allow that the slope of surface toward the south was 25 feet to the mile, the ice 100 miles to the north of here should be 2,500 feet in thickness and greater still further north.

A Grand Coast.

A hot day comes. Many warm days have preceded it. A boulder weighing 100 tons stands on a high pedestal 100 miles north of Topeka. The south wind blows. The boulder is undermined on the south side. The column breaks and the boulder is forcefully flung to the floor of ice. The ice is nearly level, but it descends gently to the south. The boulder has momentum enough in its fall to start it sliding to the south. The ice is smooth and solid. What is there to stop the boulder? Does it strike the icy pedestal of another boulder? Let it glance off, and with a graceful curve resume its course. The descent increases slightly. The momentum increases. The velocity increases greatly. Soon the force and speed becomes tremendous. It rivals a railroad train. It surpasses the pneumatic dispatch. One hundred miles an hour. Give it an hour, it ought to reach its destination.

The ice over which it slides is growing dirty and hummocky. The friction is insufficient to stop the boulder. The dirt polishes the stone. The hummocks fly before it. A train of smaller stones follow behind it. Who shall estimate the heat developed in the boulder during its rapid transit?

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* See 13th Ann. Rep. U. S. G. S., Part II, p. 70, second expedition to Mt. St. Elias, by Israel C. Russell; surface features of the Malaspina glacier.

In front yawns a precipice. It is filled with icy water. A small granite boulder of hardest texture rests on a solid limestone ledge in front of the ice-field. Water to a depth of 75 feet flows over the ledge.

The big moving boulder comes shooting over the brink of the ice. The little resting boulder is its objective point. The resting boulder is not immovable. The moving boulder is not irresistible. The little boulder does not sink crushed out of sight into the limestone. The big boulder does not get broken into a thousand pieces and scattered over the surrounding country. The water breaks the force of the big boulder's fall. The little boulder breaks the big boulder's back.

Or is it broken by the sudden cooling by immersion in the icy water?

Does sliding any distance over the ice at the rate of 100 miles an hour polish a stone as much as sliding the same distance over the ground under the ice at the rate of 100 miles in a thousand years? Why not better?

My story is told. I have attempted in my feeble way to account for the high polish some of these stones have; to account for how boulders within a hundred miles or more of the edge of the ice-field may become suddenly transported to the terminal moraine on retreat of the ice; and to explain how some of the boulders may have become broken.

I here present a map of the counties of Shawnee and Wabaunsee, showing the course of the moraine across them, and the probable location of several glacial lakes.

THE McPHERSON EQUUS BEDS.

By J. W. BEEDE, Topeka, Kan. Read before the Academy January 1, 1897.

There is a formation of considerable economic and scientific interest located in McPherson, western Marion, Harvey, and northeastern Reno counties. A large channel is carved out of the Permian shales, and, in the northern part, Dakota sandstone. Its eastern limit is a line trending north and south along the west side of Sand creek to a place a few miles north and west of Lehigh, Marion county. Here it turns westward about 20 miles, then northward to the Smoky Hill river. Its western boundary, beginning at the Smoky Hill river, runs just east of Edwards creek to the Little Arkansas river, south of which the sand-hills seem to encroach upon its area. It is well shown in the wells at Halstead, and in all probability extends to the Arkansas river. The "Tertiary Grit," referred to by Professor Hay,* just west of Wichita, is probably an outcrop of this formation, as, on the margins of the area and the isolated patches, the sand is imbedded in a limy matrix which makes it resemble the Tertiary grit farther west.

Over the deeper portions of the channel and well to the western edge lies a chain of lakes and basins extending from the large basin two miles west of McPherson to the Arkansas river, south of Patterson. The area north of the Little Arkansas river is about 800 square miles. South of it, it is probably 100 square miles, exclusive of the sand-hills.

TOPOGRAPHY.

The rough surface of the Permian to the east, the Dakota to the north, and the peculiar topography of the sand-hills to the southwest, form a marked contrast to the monotonously level surface of the Equus beds area. There are several

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* Bull. 57, U. S. Geol. Surv., p. 34, fig. 9.